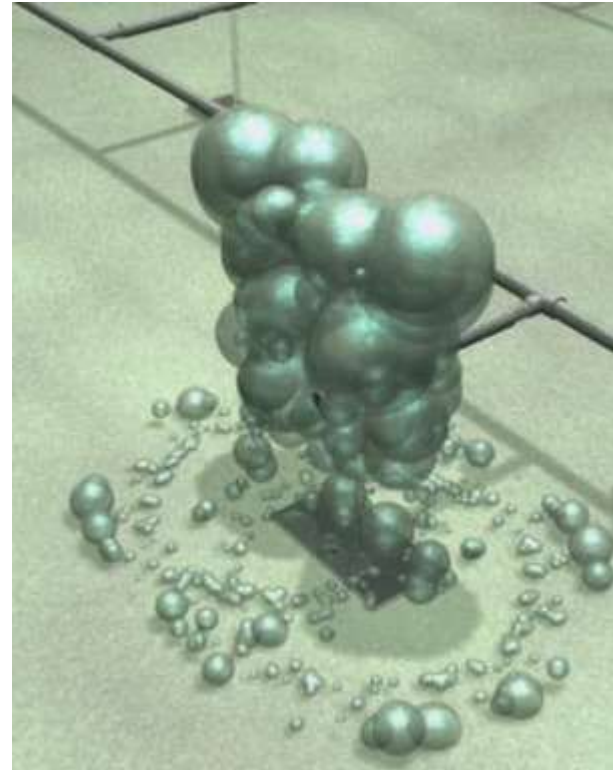


*Use of Compressed Gas
For Cost Effective Mixing and
Biological Nutrient Removal (BNR)*



Presentation Overview

- Biological Nutrient Removal Basics
- Mixing Technology Alternatives
- Compressed Gas Mixing
- Application Experiences
 - Gwinnett County, GA - F. Wayne Hill WRF
 - Mt. Pleasant, SC – Center Street WWTP
 - Warren, MI WWTP
- Summary and Questions





Biological Nutrient Removal Basics

Biological Nutrient Removal Basics

- Nitrogen & phosphorus are the primary causes of eutrophication in surface waters
 - Algal blooms, low dissolved oxygen, fish kills
- Effort to reduce nutrient impairment results in more stringent effluent limits
- Biological nutrient removal (TN & TP) occurs through the use of microorganism selection and controlled environmental conditions



Total Nitrogen Removal

- Primary removal process is nitrification and denitrification
- Process must have aerobic zone for nitrification and an anoxic zone for denitrification with nitrate rich mixed liquor return

Total Phosphorus Removal

- Comprised of soluble and particulate phosphorus
- Particulate phosphorus removed through solids removal
- Soluble phosphorus removed by microbial uptake through phosphorus accumulating organisms (PAOs)
- Process must have an anaerobic zone free of dissolved oxygen and nitrate for phosphorus release and an aerobic zone for phosphorus uptake in excess

Anoxic / Anaerobic Mixing

- In both cases, mixing of the anoxic / anaerobic zones require:
 - Mixing of basin contents
 - Mixing of influent streams
 - Without introduction of free oxygen
- Objectives and considerations of mixing technology are:
 - Maintain optimum conditions for nutrient removal
 - Provide effective and efficient mixing
 - Be low maintenance and provide low operating cost
 - Produce a low life cycle cost



Mixing Technology Alternatives

Traditional Point Source Mixing

- Historical industry standard
- Maintenance expense is the key challenge
 - Hair and ragging
 - Seal failure
 - Gearbox maintenance
 - Reliability
 - Quantity of mixers
- Maintenance points all over the plant
- Energy cost comparatively high
- Construction and capital cost affected by basin configuration

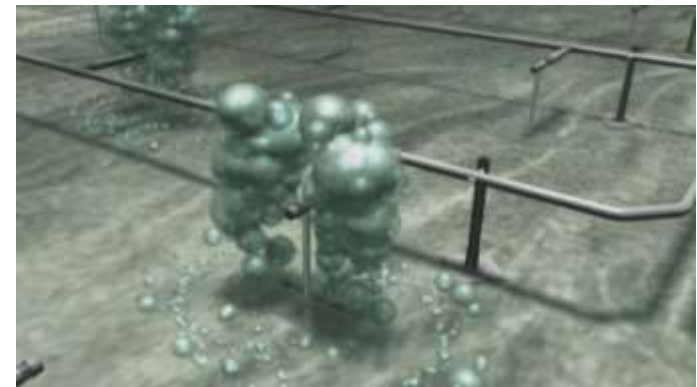




Compressed Gas Mixing

Compressed Gas Mixing

- Compressed gas mixing creates solutions that:
 - Save energy
 - Reduce maintenance
 - Address nutrient removal
- Effective mixing and efficient operation
 - Uniform distribution of mixing energy
 - Guarantee < 10% coefficient of variation (CV)
 - 60% or more energy savings
- Highly scalable
 - Once compressor replaces over multiple mixers
- Flexible design
 - Any basin footprint, depth or slope
- Field optimized operational parameters



Compressed Gas Mixing

- Intermittent and sequential short bursts of compressed gas introduced into the fluid
- Large compressed gas volumes expand upward and outward
- Expanding bubbles provide controlled turbulence, fluid currents and provide mixing
- Does so with negligible amount of oxygen transfer due to low surface area to volume ratio
- Ideal for Anoxic and Anaerobic Mixing Environments

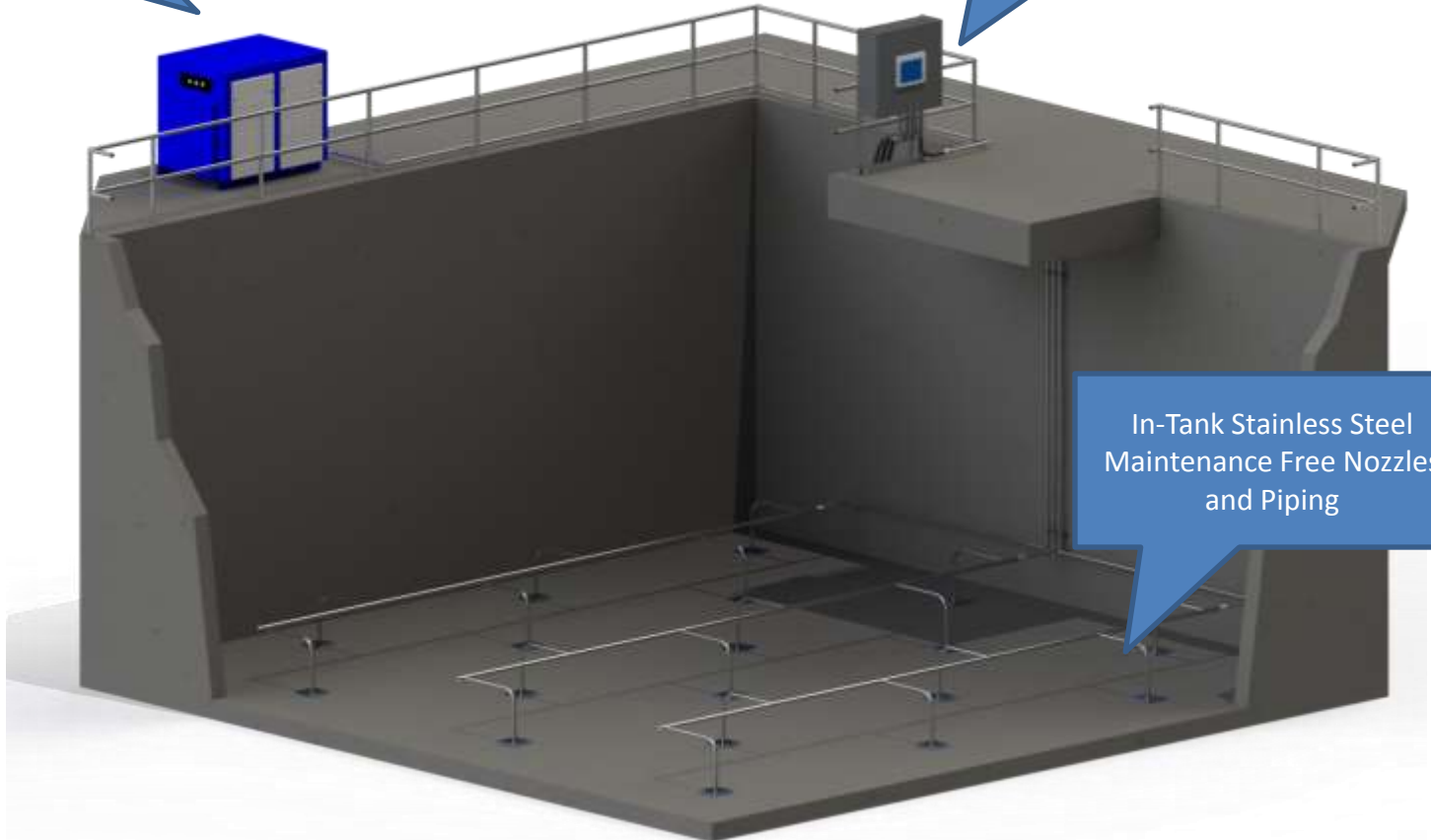


Compressed Gas Mixing Overview

Low Pressure Rotary Screw Compressor w/
Receiver Tank(s)

Local Valve Panel w/ HMI
Controls Firing Parameters of
Pressure, Frequency, Duration
and Sequence

In-Tank Stainless Steel
Maintenance Free Nozzles
and Piping



Mixing Power Comparison

- Rules-of-Thumb mixing power comparison have been derived through empirical field data in activated sludge applications

Technology	Power (HP/1,000 ft ³)
Floating and Submersible (direct-drive) Mixers	0.25 – 0.3
Long-Blade (gear reduced) Mixers	0.18
Vertical Turbine and Hyperbolic	0.12 – 0.15
Compressed Gas (improves with increasing depth)	0.065 – 0.1

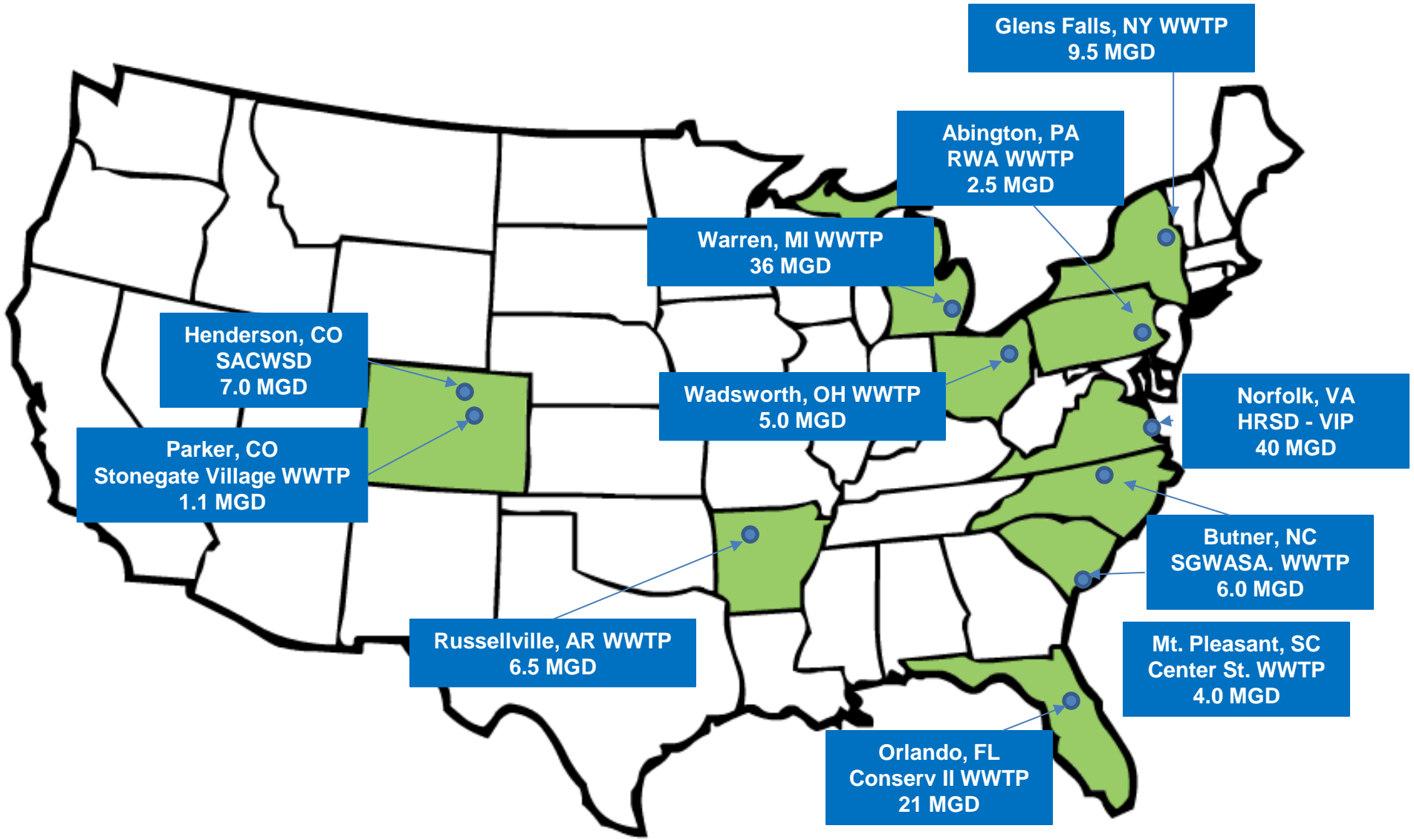
Lowest operating power requirements coupled with reduced maintenance yields 20-year PW savings of approximately \$100,00 per MGD of treatment capacity.



Application Experiences



ENVIROMIX BNR Installations





Gwinnett County, GA – F. Wayne Hill WRF

Comparative Analysis

- Professor Emeritus Clifford W. Randall of Virginia Tech University
- F. Wayne Hill Water Resources Center, Gwinnett County, GA
- 60 MGD advanced nutrient removal water reclamation facility
- Compressed gas mixing system and mechanical mixing system installed in two cells of one train
- Existing 15-HP submersible mechanical mixers with controls
- Compressed gas mixing system consisted of an rotary screw compressor, floor-mounted nozzles, piping, and controls



F. Wayne Hill WRC TSS Mixing Study

BioMix

	1/28/2010 AM			1/28/2010 PM			1/29/2010 AM			1/29/2010 PM		
	1*	2*	3*	1	2	3	1	2	3	1	2	3
J	3860	3700	3740	3840	3820	3910	4760	4610	4600	4600	4700	4910
K	3880	3860	3780	3930	3930	4100	4580	4630	4680	4680	4650	4600
L	3320	3260	3400	4800	4120	4070	4750	4710	4660	4770	4670	4650
M	3680	3470	3310	4500	3950	4150	4660	4540	4600	4650	4630	4670
N	3740	3650	3650	4250	4250	4360	4700	4640	4650	4650	4590	4640
P	3760	3580	3750	4080	3960	4080	4740	4740	4660	5310	4840	4710
Q	3690	3510	3620	4100	3980	4100	4640	4680	4710	4510	4580	4720
Ave	3704.3	3575.7	3607.1	4214.3	4001.4	4110.0	4690.0	4650.0	4651.4	4738.6	4665.7	4700.0
StdDev	186.2	190.2	183.1	336.1	140.6	133.4	66.6	66.8	40.2	264.0	87.7	101.3
Ave	3629.0			4108.6			4663.8			4701.4		
StdDev	185.6			230.4			59.3			165.0		
CV	5%			6%			1%			4%		

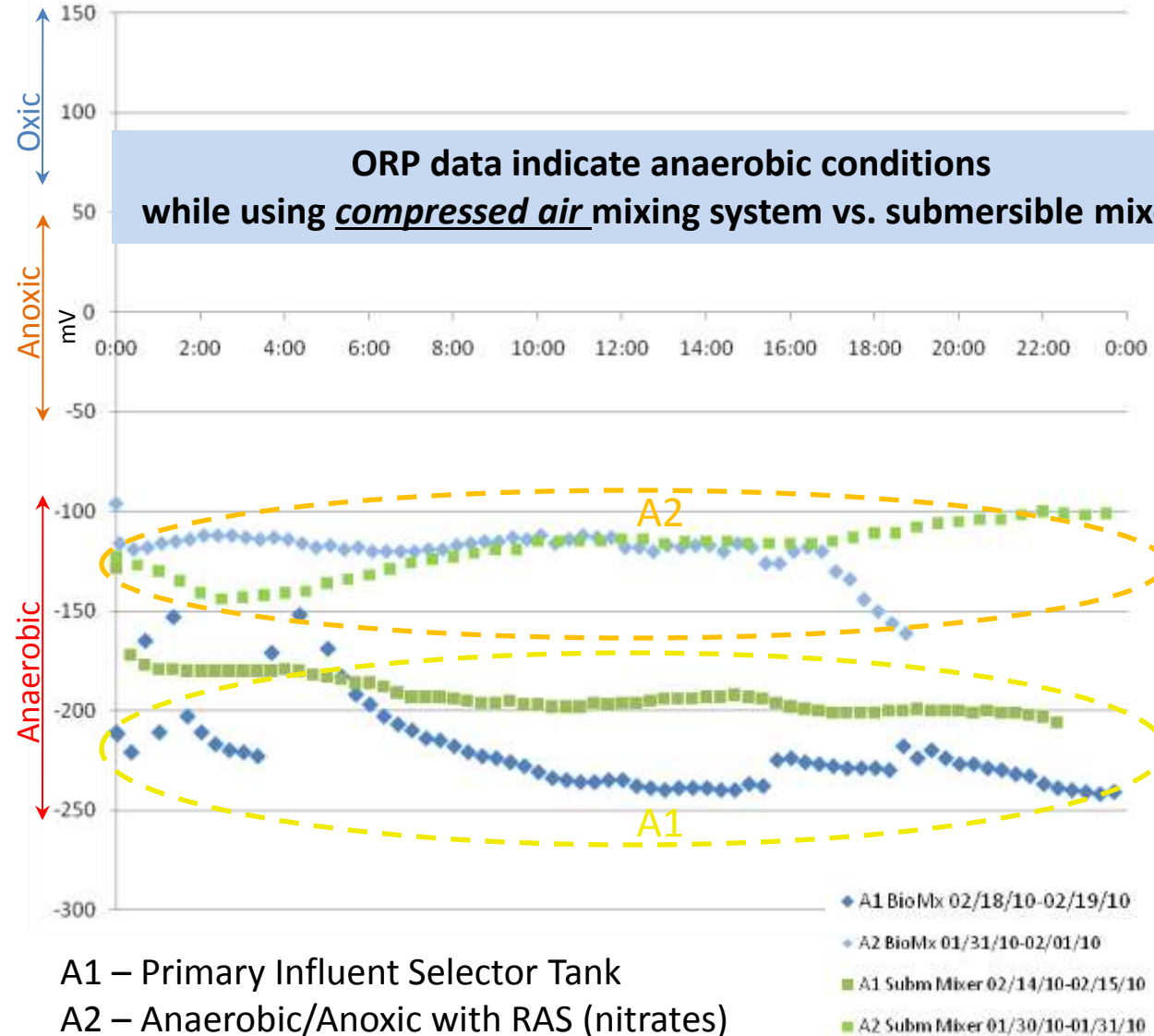
Submersible Mixer

	1/26/2010 AM			1/26/2010 PM			1/27/2010 AM			1/27/2010 PM		
	1	2	3	1	2	3	1	2	3	1	2	3
J	5110	5170	5170	4400	4330	4350	3350	3390	3360	3820	3920	3990
K	5040	5090	5100	4270	4340	4430	3310	3310	3310	3750	3930	3880
L	4720	4990	4880	3600	4200	4320	3010	3110	3150	3390	3850	3860
M	5030	5030	5120	4430	4210	4230	3300	3220	3350	3860	3870	3850
N	5120	5230	5090	4220	4470	4220	3390	3360	3350	3840	4050	3960
P	5070	5000	5070	4520	4420	4320	3240	3300	3250	3990	3850	3920
Q	5020	5010	5050	4620	4700	4540	3290	3310	3230	3960	3980	4020
Ave	5015.7	5074.3	5068.6	4294.3	4381.4	4344.3	3270.0	3285.7	3285.7	3801.4	3921.4	3925.7
StdDev	136.0	93.4	91.5	335.4	172.0	112.1	124.0	94.0	78.7	199.1	74.0	66.3
Ave	5052.9			4340.0			3280.5			3882.9		
StdDev	106.8			218.4			95.8			135.4		
CV	2%			5%			3%			3%		

Train 10, Tank A2

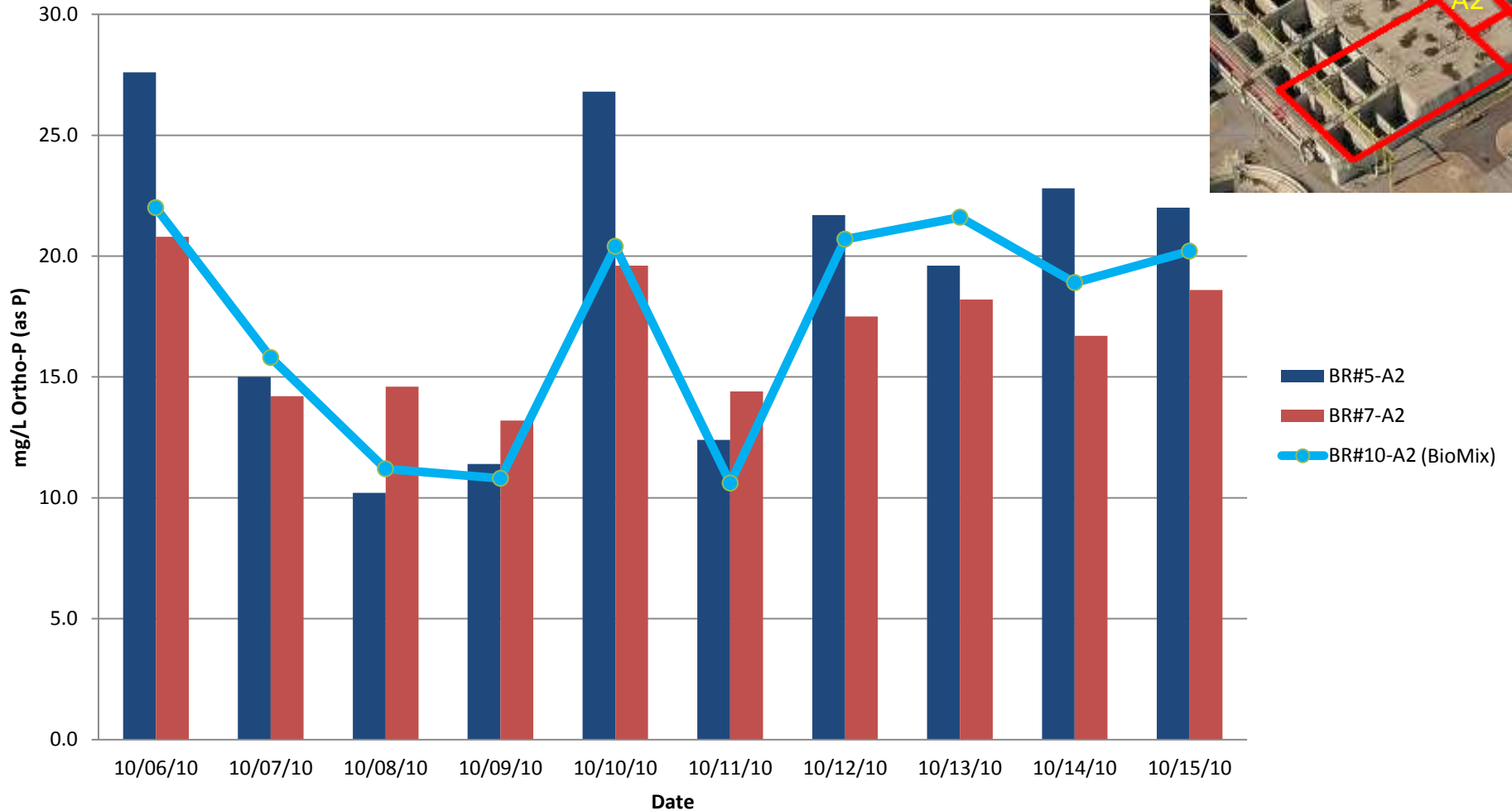
- *1 Samples taken 2' below top
 - *2 Samples taken mid-depth
 - *3 Samples taken 2' above bottom
- Cell Volume = 54,120 cf, 404,818 gal.

F. Wayne Hill WRC ORP Study



A1 Cell Mixing	Date	ORP, mV 95 th Percentile
BioMx	02/01/2010	-158
	02/17/2010	-196
	02/18/2010	-160
Submersible Mixer	01/29/2010	-117
	02/12/2010	-173
	02/14/2010	-179
A2 Cell Mixing		
BioMx	01/31/2010	-112
Submersible Mixer	01/30/2010	-102
	02/15/2010	-178

Ortho-P (as P) for Respective Anaerobic Selector Cells Parallel Process Trains, Cells A2 F. Wayne Hill WRC, Gwinnett County GA



Energy Comparison Compressed Gas Mixing vs. Submersible Mixers

	Submersible Mixer (x3)	BioMix
Amps	66.00	15.14
Volts	467.65	483.00
Power Factor	0.55	0.93
Horsepower	39.42	15.79
HP/1000 ft ³	0.243	0.097
Kilowatts	29.40	11.78
\$/Yr @ \$0.06/kW-Hr	\$15,453	\$6,192
\$/Yr @ \$0.10/kW-Hr	\$25,754	\$10,319
\$/Yr @ \$0.15/kW-Hr	\$38,632	\$15,479

60% Savings



Mt. Pleasant, SC – Center Street WWTP

Overview

- 3.7 MGD wastewater treatment plant
- Upgrade providing improved treatment and increased capacity
- Replaced inefficient PD blowers and coarse bubble aeration in flow EQ basins
- Installed to provide anoxic mixing in two converted primary clarifiers



Overview

- Qualified for Green Project Reserve (GPR) funding
- GPR Business Case projected 70% decrease in power demand versus alternative mixing technology
- Added benefit of no in-tank maintenance



Anoxic Tanks

	BioMix™	Mixers
Power (BHP)	6.5	14.7
Annual Energy Cost	\$4,180	\$9,660
20-PW Energy Cost	\$90,530	\$204,750



Equalization Tanks

	BioMix™	CB Air
Power (BHP)	14.1	60.3
Annual Energy Cost	\$7,370	\$39,080
20-PW Energy Cost	\$196,390	\$839,870



Notes:

1. Mixers at 0.3 HP/1,000 ft³, Coarse Bubble at 15 scfm/1,000 ft³
2. \$0.10/kWh Energy Cost
3. PW Cost; 20 years, 3% Interest, 4% Inflation

Performance Results

- 25 Hp rotary screw VFD compressors
- $\approx 75 \text{ ft}^2$ / nozzle
- Mixing efficiency $\approx 0.13 \text{ HP}/1000 \text{ ft}^3$ of tank volume
- Firing Parameters
 - Five headers per tank
 - Frequency 5 sec, duration 0.65 sec

Anoxic Tank No. 1 Mixing Test

- TSS average 3,300 mg/l
- TSS range 3,250 – 3,500 mg/l
- Provides uniform mixing, $\approx 3\% \text{ Cv}$



Anoxic Tank No. 2 Mixing Test

- TSS average 3,770 mg/l
- TSS range 3,750 – 3,800 mg/l
- Provides uniform mixing, $\approx 1\% \text{ Cv}$



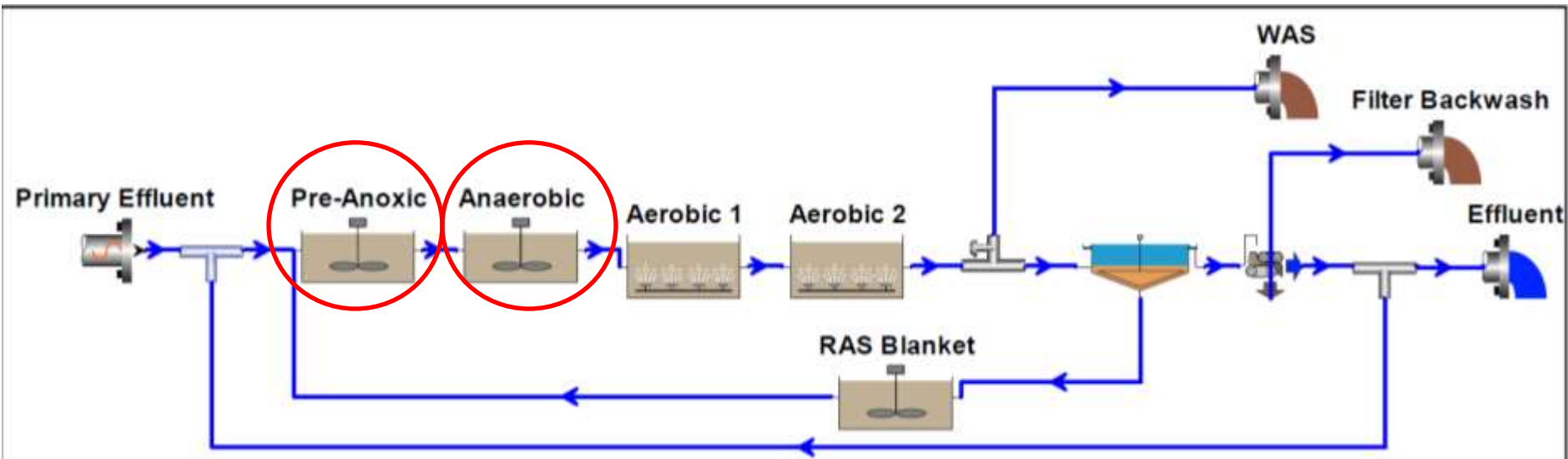
Warren, MI – Warren WWTP

Overview

- 36 MGD wastewater treatment plant
- Part of a JCI performance contract for energy and operational savings
- Conversion from chemical phosphorus removal to biological removal
- Baffled anaerobic selectors installed at influent end of four aeration basins
 - Removal of fine bubble diffusers
 - Installation of compressed gas mixing system
- Original alternative 12 vertical entry, hyperbolic mixers at 36 bhp exceeded ESPC business case

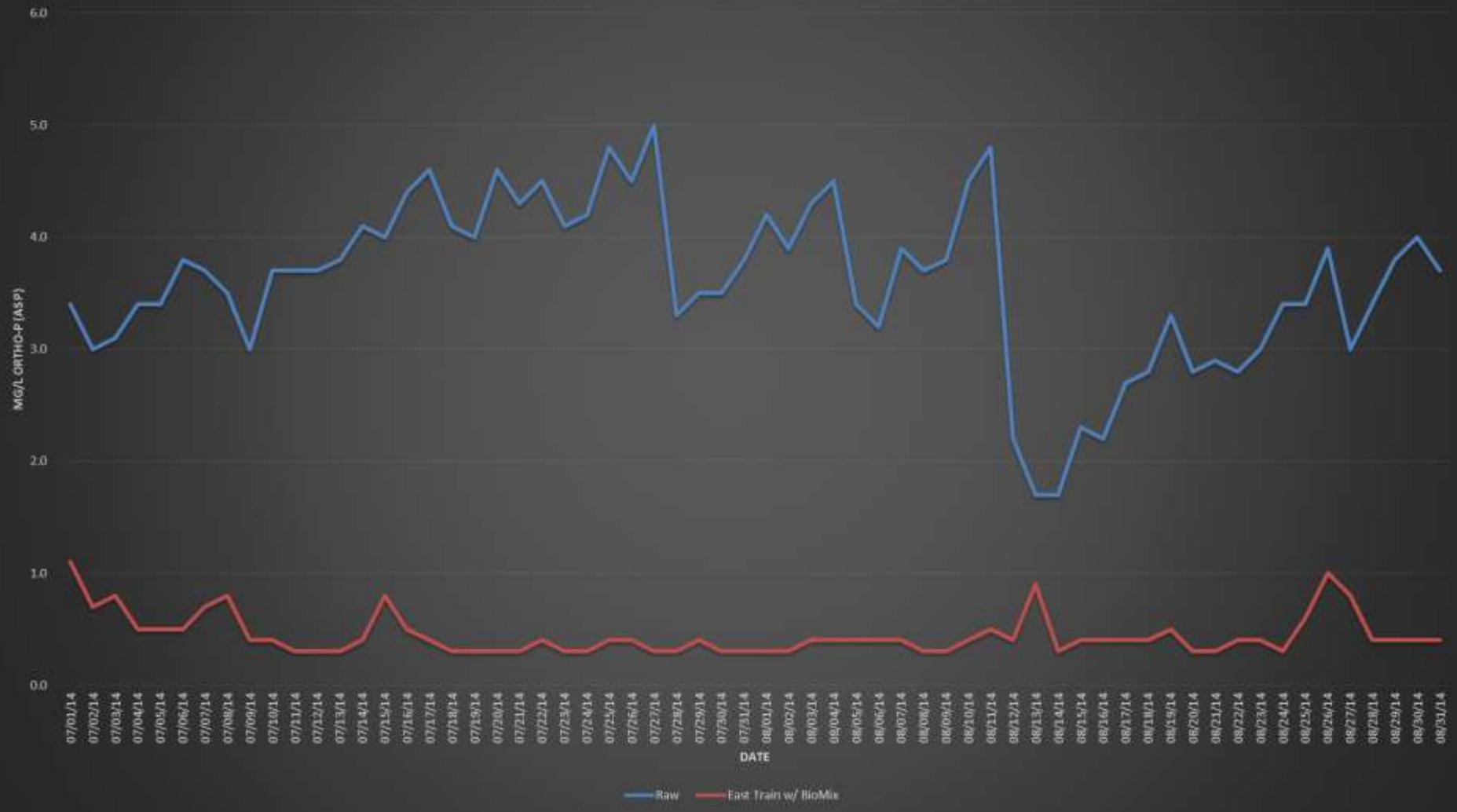


Process Modifications to Facilitate Biological Phosphorous Removal



- **Pre-Anoxic Zone**
 - Denitrification to limit the amount RAS-borne nitrates entering Anaerobic Zone
- **Anaerobic Zone**
 - Facilitate phosphorous release under anaerobic conditions
- **Return Activated Sludge (RAS)**
 - Reduced RAS from 150% down to 75%
 - Minimize nitrates returned to the Pre-Anoxic Zones

Warren, MI - Total P Effluent Concentration Comparison
BioP Removal with Anaerobic Selectors and BioMix



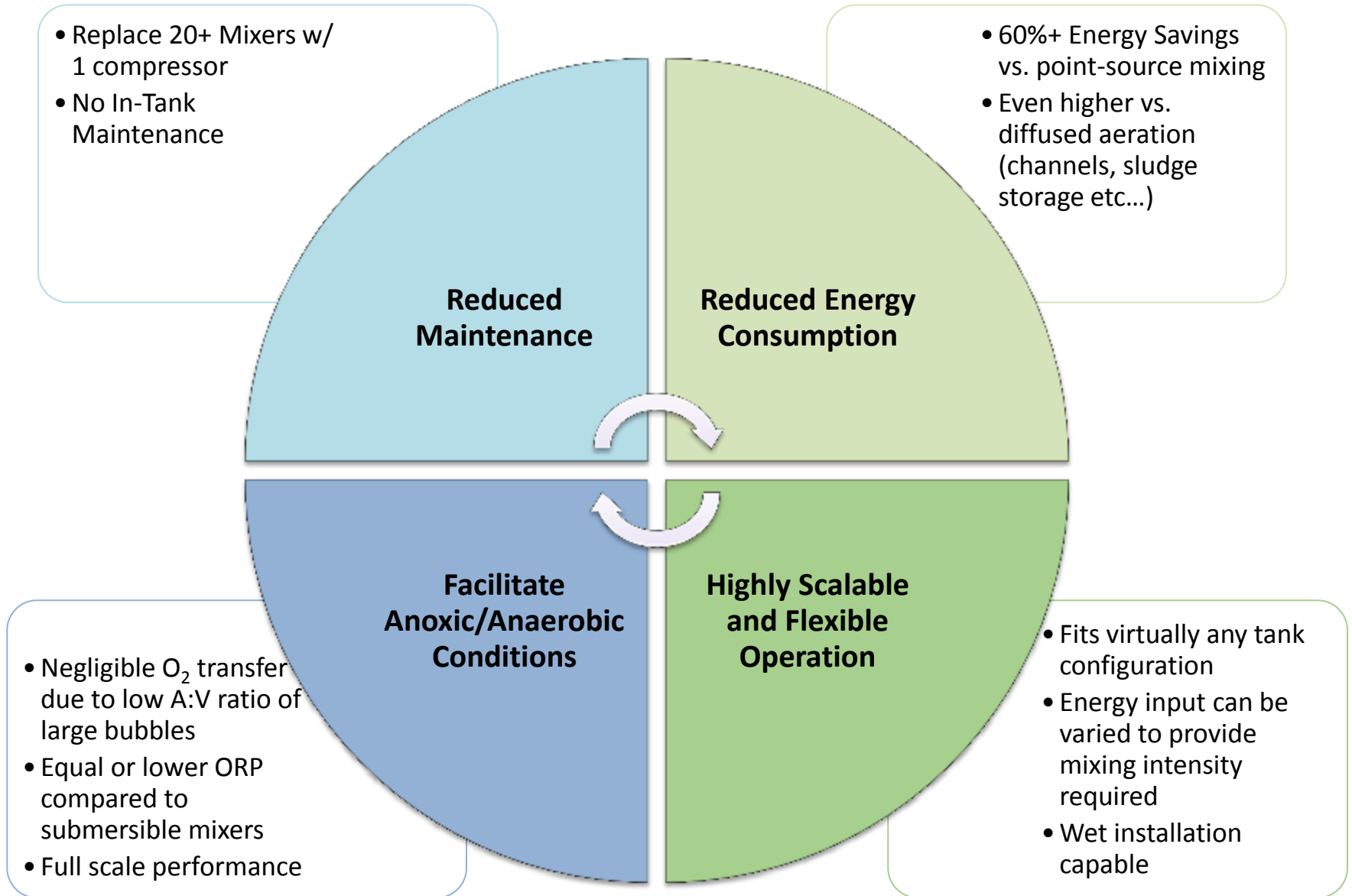
Performance Results

- 15 Hp rotary screw compressor
- $\approx 75 \text{ ft}^2$ / nozzle
- Provides uniform mixing, $< 10\% \text{ Cv}$
- Mixing efficiency $\approx 0.1 \text{ HP}/1000 \text{ ft}^3$ of tank volume
- Achieving effluent total phosphorus of $< 0.35 \text{ mg/l}$
- Phosphorus removal efficiency better than chemical precipitation
- Improved sludge settling, reduced RAS rate
- Elimination of chemical precipitation
- \$125,000 - \$150,000 annual FeCl_3 savings





Summary



Anoxic/Anaerobic Mixing

Low O₂ Demand/Mixing Limited Aeration Zones
(De-couple Aeration and Mixing)

Channel Mixing

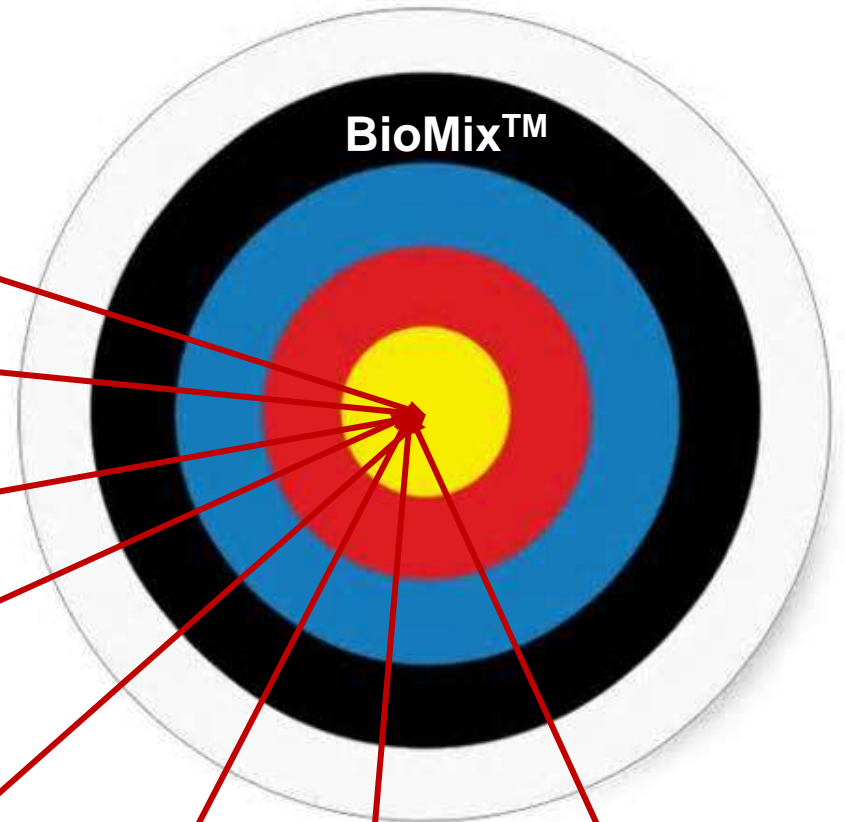
Sludge Storage

Equalization/Storm Water Holding

Aerobic SHT and Digesters
(De-couple Aeration and Mixing)

Septage Receiving

Anaerobic Digesters



Thank you for your participation

